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USING THE OEE TOOL AS AN INDICATOR TO INCREASE PRODUCTION EFFICIENCY

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Abstract: The article presents the use of the OEE tool in a production plant. The aim of the article was to verify whether the use of the OEE indicator will indicate where time is wasted in production. Does the integration of individual programs: classes suchas; APS, MES, ERP, CMMS contribute to the production department achieving better production efficiency? Theoretical considerations were supplemented with an analysis of the production process of an injection molding machine in a plastics processing plant.

Keywords: production efficency, OEE, System integration: APS, MES, ERP, CMMS

JEL classification: C22, L11, L15

INTRODUCTION

Implementing the ERP (Enterprise Resource Planning), APS (Advanced planning and scheduling), MES (Manufacturing Execution System) or CMMS (Computerised Maintenance Management Systems) softwares into production shortens cycle times, and boosts company profits. However, a German study by IDC reveals that 90% of respondents spend excessive time aligning with different production process stages. Inefficient communication leads to production bottlenecks. Dmowski et al. suggest that deepening cooperation between people and manufacturing devices can increase productivity by 25% and departmental efficiency by 30%. The author emphasizes full integration of automated production parts for optimal resource use. The diagram in Figure 1 illustrates the software facilitating collaboration within the production department and the corresponding information flows.

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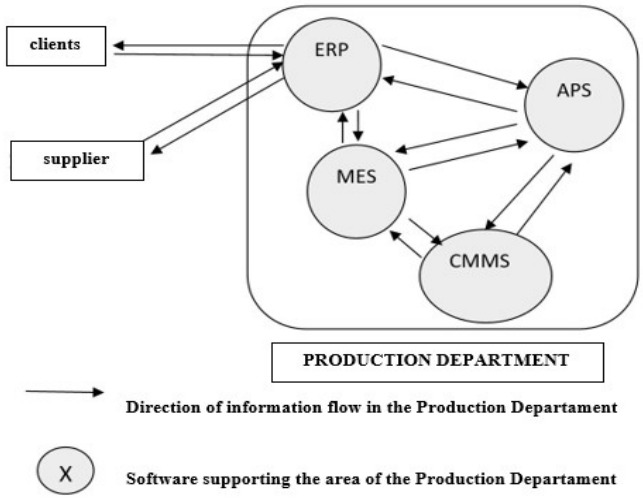
Figure 1. Individual parts of the production department supported by software: ERP, APS, MES, CMMS, and the direction of information flow between them



Source: own elaboration

Communication within the automated production departments (Figure 1.) primarily relies on telephone calls or emails with Excel-type sheets exchanged between the departments, facilitated by employees utilizing ERP-class software. Data, including HR details and warehouse status, is entered into ERP systems and then transmitted to those involved in production planning (APS).

However, this communication method often introduces significant noise, leading to potential information transmission issues. In one surveyed enterprise employing two planners, duplication of information regarding available semi-finished products in the warehouse occurs between the data handling department (ERP) and logistics department (ERP). Planners may lack information about reservations, potentially causing delays in order execution.

To prevent planning errors, planners must communicate with each other to determine the necessary raw material quantities based on actual warehouse availability. In cases of missing raw materials, planners (APS) must inform (ERP) to reserve or order semi-finished products, even from external sources. For internally produced items, ERP must log the execution of internal orders and transfer this information to planning employees (APS).

When placing orders with suppliers, those entering orders into (ERP) wait to ensure delivery profitability while maintaining minimum production costs. Timely information from the production department, such as raw material usage or machine downtime, reaches planning employees (APS) only after the shift or order completion, causing additional time and financial losses. The scheduler (APS) may

inquire about machine downtime reasons from the shift master (MES) after the fact, learning about issues like material color changes, failures, defects, or incorrect machine settings that impacted raw material consumption. Rapid dissemination of such information to planners and logistics (ERP) is crucial for material ordering in ongoing production orders.

THE IMPORTANCE OF THE OEE INDICATOR FOR ACHIEVING OPTIMAL USE OF PRODUCTION EQUIPMENT

The main determinant describing the effectiveness of the use of technical means in the enterprise is the indicator of the total efficiency of machines/use of equipment OEE (Overall Equipment Effectiveness - OEE), which can also have the meaning: Total Equipment Efficiency or Equipment Performance Index. This indicator allows you to make key decisions regarding the manufacturing process on an ongoing basis. Its main components are the availability of the machine, its use (efficiency), and quality [PN-EN 15341:2007 Maintenance 2007, MP2 IQ Solutions, company documents]. Its percentage result, which is the product of the components, informs how efficiently the machine or even the entire production line and the employees operating the devices work.

Machine availability is expressed as a ratio of machine working time, the so-called operational time, to the planned production time. Its value below 100% means that there has been an unforeseen stoppage of the machine, e.g. a failure or additional setting of the machine may have occurred [Mróz 2012; Biały, Hąbek 2016].

Performance (efficiency) is expressed as the ratio of the time the machine is available to the time it is working. This indicator informs what time is necessary to complete the order (number of valuable products produced in a given time). At the same time, if the obtained result is below 100%, it gives knowledge of what part of the assumed production volume was produced in a given time [Mróz 2013; Biały, Hąbek 2016].

Quality expressed in the form of machine working time informs about the efficiency of the use of time and its work. When the value of the obtained result is below 100%, it means that a certain time range of the machine's operation produced products of defective quality. Only the quick reaction of the operator can unravel what errors have caused the machine's production quality to deteriorate.

The main purpose of determining the OEE indicator is to find, and search for which of the three analyzed components of the machine's work, losses are generated. Table No. 1 below, shows the three components of the OEE indicator along with possible losses in the examined areas. According to World Class recommendations, machine availability should be at the level of 90%, its performance at the level of 95%, and the quality of products made at the level of 99%.After entering the individual results into formula No. (1) below, the manufacturing company should

obtain an OEE indicator of 85% [https://www.oee.com 2023, WMP SYSTEM, OEE 2023].

$$OEE = P \times Q \times A \tag{1}$$

where:

P – performance computed as: $P = \frac{wt}{tdp \times \text{number of machines}}$, (2)

where:

wt – working time of all machines in a given period,
tdp – time duration of the period,

Q – quality computed as: $Q = \frac{number\ of\ good}{number\ of\ all}$, (3)

where:

number of good – number of good pieces produced in the period,
number of all – number of all pieces produced in the period,

A – availability computed as: $A = \frac{\sum_{i=1}^{\text{number od cycle}} ct_i}{\text{number of cycle}}$, (4)

where:

ct_i – cycle time index computed as: $ct_i = \begin{cases} rc/tc & \text{if } rc < tc \\ 1 & \text{if } rc \geq tc \end{cases}$, (5)

rc - real time of a single cycle,
tc - assumed single cycle time based on technology.

This is a result that is extremely difficult to achieve, especially when the production line requires many machine changes. In the case when the machines work in a three-shift system and a single element, is mass-produced, a high index value can be obtained. According to World Class, this value is achieved by global producers, while a score of 70% proves to be an excellent producer, while a level of 50% proves to be a good producer. you. As a rule, most manufacturers declare achieving an OEE indicator of 60%. In addition, more manufacturing companies achieve 45% OEE than companies that oscillate around 85% [https://www.oee.com 2023, WMP SYSTEM, OEE 2023].

Table 1 Losses in machine operation assigned to the three components of the OEE indicator

Components of the OEE indicator	Losses in machine operation
Availability	– failures, – too long changeover time
Performance	– machine idle – minor short downtimes (up to 10 minutes), – reduced machine speed
Quality	– deficiencies – production losses during start-up

Source: https://leantrix.com/pl/wskaznik-oee/ [access: May 20, 2023]

According to Krasón P. [Krasón 2016] OEE is an extremely useful tool. However, it involves a certain risk, as the obtained result will be as valuable and reliable as the methods of its calculation were true and credible [https://leantrix.com/pl/wskaznik-oee/ 2023; Krasón 2016]. Reliability in providing the time when a given loss occurred and interpreting this event and answering questions, e.g. was the machine downtime part of the operational plan or did it result unexpectedly? Was the resulting amount of product quality losses taken into account during production and not recognized as a loss at that time? At what time did the operator record the machine stoppage? These are the factors that significantly affect the result of the obtained OEE and the entered data.

CASE STUDY

The subject of the research is a plastics processing company for the automotive industry. The company is located in the Podkarpackie Voivodeship and has two production halls, approximately 5 km apart. The total number of injection molding machines is 63 pieces. The company employs three planners. Production workers work in a three-shift cycle. The main product of the company is the so-called aesthetic elements, i.e. all elements made of plastic, constituting the internal equipment of a passenger car. Visible to the user inside the passenger car. The operating parameters of the injection molding machines vary depending on the size of the produced element: six small elements. Small parts are produced in 15-second cycles, four medium-sized parts in 25-second cycles and during this time the machine produces 6 elements. Medium elements in the amount of 4 pieces are created within 25 seconds. Big one big y element is 1 piece in cycles of 45 seconds.

The analyzed company does not have an integrated information flow system, but it has all the above-mentioned software supporting the work of people in the production department. The article aims to try to estimate the extent to which the integration of individual software, i.e. the APS, ERP, MES, and CMMS class, affects the efficiency of the production department compared to the conditions when the plant operates without such support. The OEE indicator, as the main tool for determining the effectiveness of the machine's operation, will be used for this purpose. The author of the article decided to analyze the work of one of the 63 injection molding machines that produce large elements. The pace of the machine's work is 1 finished element every 45 seconds. The order covered the production of a total of 5,400 right-hand car doors and doors. This order was planned for execution with one injection molding machine, operating in three shifts for three consecutive days. Assuming Theoretically, OEE at 100% should mean that the machine could produce 5,760 units at that time. This is an unrealistic result, if only due to the fact that you need to change the emblem in the mold that is already installed inside the injection molding machine. The scheduler assumes that it needs 30 minutes, or 1800 seconds, to complete this activity. This means that the machine will make 40 fewer

products already at the planning stage. However, this number is not counted as a loss, but only as part of the necessary production, and therefore not having this amount does not affect OEE. In the case of changing the previously used mold or the need to warm up the mold before production, and not just replacing the emblem, the estimated time is in the range of 2-4 hours. it is from 2 hours to even 8 hours. In the case of this order, in addition to this order, the planner added 4 hours of possible machine downtime, resulting, for example, from a potential failure or lack of communication between production departments. Such assumptions already reduce the machine performance by 26%, and yet the ego does not reduce the OEE indicator for the order.

The injection molding machine operator initiated a production order by changing the mold emblem, causing a 38-minute changeover instead of the planned 30 minutes, resulting in an 8-minute machine loss and 11 fewer pieces produced. The second shift, with a new operator, faced initial productivity issues, managing only 55 pieces in the first hour and needing an adjustment to machine working time. The mechanic's intervention extended the cycle time to 50 seconds per element, reducing production by approximately 8 pieces and introducing defects due to overheating.

The defective pieces went unnoticed during the second shift, contributing to a loss of 56 pieces and 25 defective ones. The issue persisted through the third shift, resulting in 29 defective pieces, detected only on the fourth shift by quality control. Restoring original settings took 20 minutes, causing a loss of 27 units. An unknown error in the last hour of the third shift led to 80 fewer pieces.

Maintenance attempted repairs during the fifth shift, replacing a damaged ejector and resulting in a 6-hour downtime, causing a loss of 480 pieces. The machine produced 22 more defective pieces in the first hour after repairs. The next three shifts were uninterrupted, but there were 2 hours of downtime due to issues like late carton placement, resulting in 192 defective products.

During the ninth shift, insufficient material preparation led to 5 defective pieces in the sixth hour, followed by machine stops due to raw material shortages. The second planner's oversight in updating the production schedule caused a conflict with raw material allocation for another order.Table 2 is a summary of one order with the resulting losses in production for one of the 63 machines.

Table 2. The course of order execution with the use of an injection molding machine along with emerging losses

shift	Causes of loss	Plan		Loss		Component of OEE
		assumed	real	time, min	number of units	
first	assembly of the emblem	30 min	38 min	8	11	availability
second	injection molding machine reprogramming	0 min	5 min	5	8	availability
	longer cycle work (7 hours)	45 s (560 pcs)	50 s (504 pcs)	42	56	performance
	defective products	0 pcs	25 pcs	19	25	quality
third	longer cycle time	45 sec (640 pcs)	50 sec (576 pcs)	48	64	performance
	demurrage	0 min	60 min	60	80	availability
	defective products	0 pcs	29 pcs	22	29	quality
fourth	longer cycle time (1 hour)	45 sec (80 pcs)	50 s (72 pcs)	6	8	performance
	injection molding machine reprogramming	0 min	20 min	20	27	availability
	defective products	0 pcs	25 s	19	25	quality
	failure	0 min	60 min	60	80	availability
fifth	failure, repair time	0 min	360 min	360	480	availability
	defective products	0 pcs	22	16'30	22	quality
sixth–eight (72 hours)	demurrage	0 min	120 min	120	160	availability
	defective products	0 pcs	192	144	192	quality
ninth	defective products	0 pcs	5 pcs	4	5	quality
	machine idle (lack of material)	0 min	120 min	120	160	performance
Sum				1057	1432	

Source: own elaboration

Using the above information about the operation of the injection molding machine, the author of the article made calculations in the field of use, quality, and availability of the machine. The obtained results are presented in Table 3.

Table 3. Components of the OEE indicator for the analyzed injection molding machine

Quality (pieces)		
all	5472	
good	5196	
Performance/cycle		
shift	assumed single cycle time based on technology, *ct*	Numer of cycle
first	492,3636363	584
second	471,2727273	576
third	618,9090909	632
fourth	640	640
fifth	640	640
sixth	640	640
seventh	640	640
eight	640	640
ninth	480	480
Sum	5262,545455	5472
Availability (working time)		
assumed	12960	
real	12267	

Source: own elaboration

By introducing individual values from Table 3 to the formula for the OEE indicator of a production order (1), a value of 86.44% was obtained, without taking into account the initial preparation of the machine. This indicator could be considered high, but if the calculation concerned the operation of all injection molding machines. However, the OEE indicator obtained in the analyzed example was calculated for not one machine, which had only one initial changeover and in addition was not taken into account during the injection molding machine's operation. In addition, the time of unforeseen machine downtime is added, which is also not added to the working time of the production department. In this way, the planner secures the execution of all products at a safe time. In the analyzed example, such a planned machine stoppage means 320 fewer units of production. With initial scheduling, the machine can produce 4,286 units, and with this schedule, the machine processes 580 fewer products than its capacity. If the changeover time and the planned downtime of the injection molding machine were taken into account, the OEE indicator would amount to 84.5%. Such a value for the operation of one injection molding machine working in three shifts, regardless of the other production equipment, is an unsatisfactory result. Based on this example, unforeseen failures and micro downtimes for one job and one injection molding machine are

approximately 14%, reducing machine productivity by approximately 14% when changeovers and planned downtimes are not included in the calculations, or by 15.5% after taking into account. As previously mentioned in the article, the analyzed company does not have an integrated communication system between individual departments and production areas. If the mechanic does not communicate with the planner about extending the working time of the machine, the planner may incorrectly plan subsequent orders, which will immediately be delayed in execution. If the planner does not receive information from the operator, he will learn about the production shift from employees operating ERP class software, who, after verifying the inventory, i.e. what has flowed from production after 24 hours, will provide information on this subject, usually on the next day. Reporting the failure to both (APS and CMMS) definitely eliminates time loss. The planner, having access to the system (CMMS), could track and see how long a given mold has been working in the injection molding machine. works in the injection molding machine. Scheduled cleaning or replacement could eliminate unexpected failures and the production of defective components. The planner could schedule the execution of the e-order at a different time or on a different injection molding machine. The current insight of employees operating the APS software into the ERP software would eliminate another error of duplication of the planned raw material from the warehouse.

It is also impossible to ignore the fact that the order has not been executed. 5,400 units were ordered, while. Capabilities of the machine is able to produce 5760 pieces at OEE= 100% for the order. Thus, the execution of the order was achievable. The machine produced 5,472 pieces, of which 5,196 were produced without defects. 204 pieces were missing to complete the task. At this point, another issue arises costs for failure to comply with the contract between the entrepreneur and the manufacturer. From the above description of this production information, the last shift machine was idle for two hours due to a lack of raw material. ERP employees. Ordering the right amount of raw material, employees (ERP) should also maintain the economic profitability of deliveries, i.e. the minimum order quantity that guarantees the profitability of delivery. The production company may negotiate the delivery time of the next batch of 204 items, e.g. on preferential terms for failure to meet the agreed deadline.

CONCLUSION

The OEE for a single order should be 100%, in the analyzed example OEE was 86.44%. This is a low value because a single order doesn't consider the entire company's production, e.g. planned maintenance or additional time needed for retooling. The obtained OEE shows that, yearly, the injection molding machine was either inactive or producing bad products for more than one month. A warehouse is not releasing all semi-finished products on the beginig of the order e.g. all semiproducts are being given in the stages. Automated APS, MES, and ERP could

raise the OEE result up to 9% for a given task. In the analyzed example, the injection molding machine produced a total of approximately 5% defective products (276 pieces). For a factory that has 12 injection molding machines, the potential loss could be over 3,300 products, which corresponds to a loss of over 60% for such an order. In companies where the essence of production is its scale, eliminating downtime per second is of great importance for financial results and, as a result, for entrepreneurs and their employees. Optimizing the production department is crucial for competitive advantage and profitability. Automated software integration minimizes communication errors, addressing delays, micro-changeovers, and communication gaps causing downtime and defects. Overcoming these challenges leads to substantial financial savings, providing a competitive edge. To enhance efficiency, gradual implementation of specialized IT systems for integrated automation is recommended, replacing manual OEE recording with cyclical form filling. Simulation indicates improved machine use time, enhanced supply chain control, and reduced losses. Detailed time-based data collection is vital, as short changeovers and delays significantly contribute to losses when handling multiple machines concurrently.

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